SURROUND SURVEILLANCE APPARATUS FOR MOBILE BODY

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION:

The present invention relates to a surround surveillance system for surveying surroundings of a mobile body. Specifically, the present invention relates to a surround surveillance apparatus for surveying surroundings of a mobile body for human and cargo transportation, such as a car, a train, etc.

2. DESCRIPTION OF THE RELATED ART:

In recent years, an increase in traffic accidents has become a major social problem. In particular, in a place where a plurality of roads meet (T-intersection, crossroad, or the like), various accidents may sometimes occur. For example, people rush out into the street in which cars are travelling, a car collides head-on or into the rear of another car, etc. It is believed, in general, that such accidents are caused because a field of view for both drivers and pedestrians is limited in the crossroad area, and many of the drivers and pedestrians do not pay attention to their surroundings and cannot quickly recognize dangers. Thus, improvements in a car itself, arousal of attention of drivers, improvements and

maintenance of traffic environments, etc., are highly demanded.

Conventionally, for the purpose of improving traffic environments, mirrors are installed at appropriate positions in a crossroad area such that drivers and pedestrians can see blind areas behind obstacles. However, the viewing range of a blind area which can be covered by a mirror is limited and, furthermore, a sufficient number of mirrors have not been installed.

In recent years, many large motor vehicles, such as buses and some passenger cars, have a surveillance system for checking the safety therearound, especially at a rear side of the vehicle. The system includes a surveillance camera installed in the rear of the vehicle, and a monitor provided near a driver's seat or on a dashboard. The monitor is connected to the surveillance camera via a cable. An image obtained by the surveillance camera is displayed on the monitor. However, even with such a surveillance system, the driver must check the safety of both sides of the vehicle manually using eyesight. Accordingly, in a crossroad area or the like,

in which there are blind areas due to obstacles, the driver sometimes cannot quickly recognize dangers. Furthermore, a single camera of this type has a limited field of vision such that the camera can detect obstacles and anticipate collisions only in one direction. In order to check the presence/absence of obstacles and anticipate the danger of collision over a wide range, a certain manipulation, e.g., alteration of a camera angle, is required.

Since a primary purpose of the conventional surround surveillance system for motor vehicles is surveillance in one direction, a plurality of cameras are required for watching a 360° area around a motor vehicle; i.e., it is necessary to provide four or more cameras such that each of front, rear, left, and right sides of the vehicle is provided with at least one camera.

Furthermore, in the case where a vehicle is used in an area where or at a time when the environmental temperature is decreased to or below a certain temperature, such as areas of high altitude, areas of high latitude regions, during winter, etc., during a certain period after an engine of the vehicle is started, dew may sometimes be formed on a window glass of the vehicle, and

subsequently frozen on the window. Such dew or frozen

dew, or any other factor, may sometimes fog the window,

causing difficulty for a driver to look outside from the

inside of the vehicle. For example, when the driver parks

5   the vehicle at the edge of a road, in many cases, the

driver's vehicle is close to another vehicle or a person.

When the driver starts to drive the vehicle under such

circumstances, the driver of the vehicle cannot fully

grasp the conditions around the vehicle unless the fog

10   on the window of the glass is sufficiently wiped away or

evaporated by warm air.

As a matter of course, in the case of using a motor

vehicle, a driver encounters various situations where

15   he/she is required to secure the safety around the motor

vehicle. For example, when the driver starts to drive,

the driver has to check the safety at the right, left,

and rear sides of the motor vehicle, as well as the front

side. Naturally, when the motor vehicle turns right or

20   left, or when the driver parks the motor vehicle in a

carport or drives the vehicle out of the carport, the

driver has to check the safety around the motor vehicle.

However, due to the shape and structure of the vehicle,

there are blind spots/areas, i.e., areas that the driver

cannot see directly behind and/or around the vehicle, and it is difficult for the driver to check the safety in such blind spots/areas. As a result, such blind areas impose a considerable burden on the driver.

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Furthermore, in the case of using a conventional surround surveillance system, it is necessary to provide a plurality of cameras for checking the safety in a 360° area around the vehicle. In such a case, the driver has to selectively switch the cameras from one to another, and/or turn the direction of the selected camera according to circumstances, in order to check the safety around the vehicle. Such a manipulation is a considerable burden for the driver.

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Furthermore, in the case where a window glass of a vehicle is fogged and it is difficult for a driver of the vehicle to see outside from the inside of the vehicle, the driver needs to increase the temperature inside the vehicle and wait until the fog on the window is cleared, or needs to wipe away the fog on the window so that the driver can check the safety around the vehicle manually using eyesight. In such a case, if there is means for helping the driver to check the safety around the vehicle

instead of manually using eyesight, the driver can start the vehicle in a more secure manner.

SUMMARY OF THE INVENTION

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According to one aspect of the present invention, a surround surveillance system mounted on a mobile body for surveying surroundings around the mobile body includes an omniazimuth visual system, the omniazimuth
10 visual system includes at least one omniazimuth visual sensor including an optical system capable of obtaining an image with an omniazimuth view field area therearound and capable of central projection transformation of the image into an optical image, and an imaging section
15 including an imaging lens for converting the optical image obtained by the optical system into image data, an image processor for transforming the image data into at least one of panoramic image data and perspective image data, a display section for displaying one of a panoramic image
20 corresponding to the panoramic image data and a perspective image corresponding to the perspective image data and a display control section for controlling the display section. The optical system includes a hyperboloidal mirror which has a shape of one sheet of

a two-sheeted hyperboloid, an optical axis of the hyperboloidal mirror being identical with an optical axis of the imaging lens, and the principal point of the imaging lens being located at one of focal points of the hyperboloidal mirror. The display section displays the perspective image transformed from the bird's-eye image of the mobile body and surroundings thereof.

In one embodiment of this invention, the at least one omniazimuth visual sensor is located such that a bird's-eye image of the entire mobile body and surroundings thereof is transformed into the image data.

In one embodiment of this invention, the display section simultaneously or selectively displays the panoramic image and the perspective image.

In one embodiment of this invention, the display section displays an image seen in a direction opposite to a most likely moving direction of the mobile body.

In one embodiment of this invention, the image processor transforms image data corresponding to a first area within the omniazimuth view field area around the

optical system into first perspective image data.

In one embodiment of this invention, in response to control by the display control section, the image

5   processor transforms image data corresponding to a second area within the omniazimuth view field area around the optical system which does not overlap with the first area into a second perspective image data which does not coincide with the first perspective image data.

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In one embodiment of this invention, the second area is identical to an area which is obtained by performing at least one of translational transfer processing and zoom-in/zoom-out processing on the first

15   area.

In one embodiment of this invention, the optical system is positioned such that an optical axis of the optical system is perpendicular to a most likely moving

20   direction of the mobile body.

In one embodiment of this invention, in response to control by the display control section, the display section displays an image showing the mobile body on a

display screen of the display section such that the mobile body is shown at a predetermined position on a displayed image on the display screen.

5   When displaying a bird's-eye perspective image of a mobile body and surroundings thereof, the display section preferably displays the image such that the mobile body is shown at a predetermined position on a display screen.

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According to the present invention, the display section displays a bird's-eye perspective image of a mobile body and surroundings thereof. In this case, when the display section displays a bird's-eye perspective

15   image of the entire mobile body and surroundings thereof, an operator of the mobile body can check the surroundings of the mobile body in all directions at one time.

When an omniazimuth visual sensor can directly

20   convert a bird's-eye image of an entire mobile body and surroundings thereof to image data, the display section can display a bird's-eye perspective image of the entire mobile body and surroundings thereof which is converted from the image data derived from the omniazimuth visual

sensor.

However, in some cases, an omniazimuth visual sensor cannot directly convert a bird's-eye image of an entire mobile body and surroundings thereof to image data. For example, when an omniazimuth visual sensor is positioned at a place higher than the main body (or roof) of a vehicle, the omniazimuth visual sensor can obtain a bird's-eye image of the entire vehicle and surroundings thereof which is directly seen from a position right above the vehicle. However, when the omniazimuth visual sensor is positioned at a place lower than the roof of a vehicle, a portion of the view field of the omniazimuth visual sensor is interrupted by the vehicle so that a bird's-eye image of the entire vehicle and surroundings thereof cannot be obtained.

In such a case, a plurality of perspective images obtained through a plurality of omniazimuth visual sensors may be combined to display a single bird's-eye perspective image of the entire vehicle and surroundings thereof. With such an arrangement, an operator of the mobile body can check the surroundings of the mobile body in all directions at one time.

Alternatively, vehicle image data which represents a top view image (bird's-eye image) of the vehicle which was previously captured from a position directly above the vehicle is stored in a storage section of an image processor, and the vehicle image data stored in the storage section is combined with a perspective image data obtained by converting the image obtained through the omniazimuth visual sensor, whereby the display section may display a perspective image showing the entire vehicle on a predetermined position on the display screen.

Alternatively, image data of a top view image (bird's-eye image) of the vehicle which was previously created by using computer graphics software may be stored in a storage section of an image processor, and the previously created image data may be combined with perspective image data obtained by converting an image derived from the omniazimuth visual sensor, whereby the display section may display a combined image showing the entire vehicle on a predetermined position on the display screen.

In this way, a prepared image of a mobile body and a perspective image showing the mobile body and its surroundings which is obtained through an omniazimuth visual sensor are combined into an image to be displayed.

5 From such a combined image, the operator of the mobile body can readily grasp a relative distance between the mobile body and objects around the vehicle. By using a previously captured image of the mobile body, the operator of the mobile body can readily grasp a relative distance

10 between the mobile body and objects around the vehicle with more visual reality.

In one embodiment of this invention, the display section simultaneously displays an image seen in a

15 direction opposite to a most likely moving direction of the mobile body and an image seen in a direction which is not identical or opposite to the most likely moving direction of the mobile body.

20 In one embodiment of this invention, the mobile body is a vehicle.

In one embodiment of this invention, the vehicle includes a first bumper provided at a most likely moving

direction side of the vehicle and a second bumper provided at a side of or the vehicle opposite to the most likely moving direction side. The at least one omniazimuth visual sensor includes a first omniazimuth visual sensor placed on the first bumper and a second omniazimuth visual sensor placed on the second bumper.

In one embodiment of this invention, the first omniazimuth visual sensor is placed on one of a right end and a left end of the first bumper with respect to the most likely moving direction of the vehicle. The second omniazimuth visual sensor is placed on one end of the second bumper which is diagonal to the end of the first bumper where the first omniazimuth visual sensor is placed with respect to a body of the vehicle.

In one embodiment of this invention, the display section displays an image obtained by combining a first perspective image derived from the first omniazimuth visual sensor and a second perspective image derived from the second omniazimuth visual sensor.

In one embodiment of this invention, the image processor includes a storage section for storing mobile

body image data; the image processor combines the mobile body image data from the storage section with the perspective image data derived from the optical system; and the display section displays based on the combined image data a perspective image including the image showing the mobile body.

In one embodiment of this invention, the mobile body image data is image data created by using computer graphics software.

In one embodiment of this invention, the mobile body image data is image data obtained by capturing an image of the mobile body.

In one embodiment of this invention, the omniazimuth visual system further includes a temperature measurement section for measuring an environmental temperature of the mobile body; when the environmental temperature measured by the temperature measurement section is equal to or lower than a predetermined temperature, the display section displays the perspective bird's-eye image of the mobile body and surroundings thereof after the mobile body becomes movable.

In one embodiment of this invention, when the display section displays a perspective image of an overlapping region between a display region of a perspective bird's-eye image of the mobile body and surroundings thereof which is obtained through the first omniazimuth visual sensor and a display region of a perspective bird's-eye image of the mobile body and surroundings thereof which is obtained through the second omniazimuth visual sensor, the display section displays based on control by the display control section a perspective image derived from one of the first omniazimuth visual sensor and the second omniazimuth visual sensor.

Furthermore, when the environmental temperature of the mobile body is lower than a predetermined temperature, the display section preferably displays a bird's-eye image of the mobile body and surroundings thereof after the mobile body becomes movable. In order to obtain a bird's-eye image of the mobile body and surroundings thereof, the omniazimuth visual sensor is preferably positioned such that the viewing angle of the omniazimuth visual sensor is perpendicular to a most

likely moving direction. When the mobile body is a vehicle, the omniazimuth visual sensor is positioned such that the omniazimuth visual sensor can obtain a perspective image from a direction which is 90° from the horizontal plane (direction downwardly perpendicular to the horizontal plane). When a perspective image obtained by converting an image obtained through such an omniazimuth visual sensor is displayed, the operator of the mobile body can readily check the safety around the mobile body.

In the present specification, an optical image which is central-projection-transformed by an optical system is regarded as an image around the optical system which is seen from one of a plurality of focal points of the optical system.

Hereinafter, functions of the present invention will be described.

According to the present invention, an optical system of an omniazimuth visual sensor is capable of central projection transformation of an image around the optical system. This optical system includes, for

example, a hyperboloidal mirror which has a shape of one sheet of a two-sheeted hyperboloid. In the optical system, the optical axis of the hyperboloidal mirror is identical with the optical axis of the imaging lens

5   included in the imaging section of the omniazimuth visual sensor, and the principal point of the imaging lens is located at one of the focal points of the hyperboloidal mirror.

10 An optical image obtained through such an optical system is transformed into image data by the imaging section, and the image data is transformed into at least one of a panoramic image data and a perspective image data.

15 The display section displays at least one of a panoramic image corresponding to the panoramic image data and a perspective image corresponding to the perspective image data.

20 An optical image obtained by the imaging section is regarded as an image seen from one of the focal points of the optical system. Thus, the optical image can be transformed into a panoramic image or a perspective image by performing coordinate transformation from a polar

coordinate into a rectangular coordinate.

Selection of an image to be displayed or selection
of the size of the image to be displayed is performed by
5   the display control section.

In one embodiment, an omniazimuth visual sensor
is located such that perspective bird's-eye image data
of the mobile body and surroundings thereof can be
10   obtained. When the mobile body is a vehicle, in general,
a bird's-eye image of the vehicle and surroundings thereof
can be displayed by downwardly shifting the viewing
direction of a perspective image obtained through the
omniazimuth visual sensor so as to be 90° with respect
15   to a horizontal plane.

With such a structure, the display section can
displays a perspective bird's-eye image of the mobile body
and surroundings thereof.
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As a result, the driver does not need to switch
a plurality of cameras, to select one among these cameras
for display on a display device, or to change the
orientation of the camera, as in a conventional vehicle

surveillance apparatus where each camera is designed for one directional surveillance.

The display section displays a perspective image of an area within the surrounding area of the omniazimuth visual sensor which is opposite to the most likely moving direction of the mobile body.

Alternatively, the display section can display an image obtained by performing, in response to control by the display control section, at least one of (vertical and/or horizontal) translational transfer processing (tilt/pan processing) and scale-up/scale-down (zoom-in/zoom-out) processing.

Thus, such a function is useful when the driver has to check the distance between his/her own vehicle and adjacent vehicles or obstacles: for example, especially when the driver parks the vehicle in a carport or parking lot or drives the vehicle out of the carport or parking lot, or when the driver parks or stops the vehicle as close to the edge of the adjacent vehicles or obstacles as possible.

In the present specification, the "scale-up/scale-down" operation refers to one of a scale-up operation and a scale-down operation.

5   When the optical system is positioned such that an optical axis of the optical system is perpendicular to the most likely moving direction of the mobile body, a perspective image obtained by converting an image captured by the optical system can be a bird's-eye image

10   of the entire mobile body seen from a position right above the mobile body. In such a case, for example, a driver can readily check the distance between his/her own vehicle and adjacent vehicles or obstacles when the driver parks the vehicle in a carport or parking lot or drives the

15   vehicle out of the carport or parking lot, or when the driver parks or stops the vehicle as close to the edge of the adjacent vehicles or obstacles as possible. Even if the optical axis of the optical system is not perpendicular to the horizontal plane, a desired image

20   can be obtained by changing the viewing direction of a perspective image obtained through the omniazimuth visual sensor so as to be downwardly perpendicular to the horizontal plane.

Furthermore, when the display section displays a perspective image of the mobile body in response to control by the display control section, the perspective image can be shifted such that the mobile body is shown

5   in a desired portion of the displayed perspective image (for example, the center of the displayed perspective image). In such a case, the driver of the mobile body can readily recognize the surroundings of the mobile body.

10   Furthermore, when an image of a mobile body which is previously captured or previously created by using computer graphics software is displayed on a predetermined place of the display screen of the display section, the operator of the mobile body can readily

15   recognize the positional relationship between the mobile body and objects around the mobile body (obstacles or the like).

Furthermore, the display section simultaneously

20   displays an image seen in a direction opposite to a most likely moving direction of the mobile body and an image seen in a direction which is not identical or opposite to the most likely moving direction of the mobile body. With such a structure, the driver can readily check an

area which can be seen in a direction different from the most likely moving direction. In general, an operator of the mobile body faces the most likely moving direction. Thus, it is significant in view of safety to check the

5   area which can be seen in a direction different from the most likely moving direction.

For example, when the mobile body is a vehicle, two omniazimuth visual sensors are placed such that one

10   is on a front bumper and the other is on a rear bumper, whereby the driver's blind areas can be readily observed. Especially when one omniazimuth visual sensor is placed at one of a front right corner and a front left corner of the vehicle, and the other is placed at the diagonal

15   rear corner of the vehicle, an image with about a 360° view field around the entire mobile body can be obtained near areas in close proximity to the vehicle which are the driver's blind areas.

20   Furthermore, the display section displays a perspective image obtained by combining a perspective bird's-eye image of the vehicle and surroundings thereof which is derived from an omniazimuth visual sensor placed at a front corner of the vehicle and a perspective

bird's-eye image of the vehicle and surroundings thereof which is derived from another omniazimuth visual sensor placed at a diagonal rear corner of the vehicle. With such an arrangement, images around the entire vehicle can be displayed in one display screen. Thus, the driver can readily check the safety around the vehicle.

Furthermore, in the case where the environmental temperature is decreased to or below a certain temperature, for example, in areas of high altitude, areas of high latitude regions, during winter, etc., and difficulty is caused on an operator of a mobile body in looking outside from the inside of the mobile body (when a window glass of a vehicle is fogged), the display section displays a perspective bird's-eye image of the mobile body and surroundings thereof after the mobile body becomes movable, whereby the operator of the mobile body can readily check the safety around the mobile body. For example, when the mobile body is a vehicle, an image of the surroundings of the vehicle can be displayed by downwardly shifting the viewing direction of a perspective image obtained through the omniazimuth visual sensor so as to be 90° with respect to a horizontal plane.

Thus, the invention described herein makes possible the advantages of (1) providing a surround surveillance apparatus for readily observing surroundings of a mobile body in order to reduce a driver's
5   burden and improve the safety around the mobile body, and (2) providing a surround surveillance apparatus which can enable an operator of a mobile body to quickly grasp the conditions around the mobile body after the mobile body becomes movable.

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These and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figure **1A** is a plan view showing a structure of a vehicle incorporating a surround surveillance apparatus
20   according to embodiment 1 of the present invention. Figure **1B** is a side view showing the vehicle of Figure **1A**.

Figure **1C** is a plan view showing a structure of a variation of the vehicle incorporating the surround

surveillance apparatus according to embodiment 1 of the present invention. Figure **1D** is a side view showing the vehicle of Figure **1C**.

5   Figure **2** is a block diagram showing a configuration of the surround surveillance apparatus according to embodiment 1.

        Figure **3** shows an exemplary structure of an
10 optical system used in the surround surveillance apparatus according to embodiment 1.

        Figure **4A** is a block diagram showing a structure of an image processor used in the surround surveillance
15 apparatus according to embodiment 1.

        Figure **4B** is a block diagram showing a structure of an image transformation section used in the surround surveillance apparatus according to embodiment 1.

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        Figure **5** illustrates an example of panoramic (360°) image transformation according to embodiment 1. Part **(a)** shows an input round-shape image. Part **(b)** shows a donut-shape image subjected to the panoramic image

transformation.   Part **(c)** shows a panoramic image obtained by transformation into a rectangular coordinate.

Figure **6**   illustrates   a   perspective
5   transformation in the surround surveillance apparatus according to embodiment 1.

Figure **7** shows an example of a display screen of a display section in the surround surveillance apparatus
10   according to embodiment 1.

Figure **8** shows another example of the display screen of the display section in the surround surveillance apparatus according to embodiment 1.
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Figure **9A** is a plan view showing a vehicle including a surround surveillance apparatus for a mobile body according to embodiment 2 of the present invention. Figure **9B** is a side view of the vehicle shown in Figure **9A**.
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Figure **10** shows an example of a display screen of a display section in the surround surveillance apparatus according to embodiment 2.

Figure **11** shows a division of regions on a display screen of a display section in the surround surveillance apparatus according to embodiment 2.

5   Figure **12A** is a plan view showing a structure of a vehicle incorporating a surround surveillance apparatus according to embodiment 3 of the present invention. Figure **12B** is a side view showing the vehicle of Figure **12A**.

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Figure **13** is a block diagram showing a configuration of the surround surveillance apparatus according to embodiment 3.

15   DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be described with reference to the drawings.

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(Embodiment 1)

Figure **1A** is a plan view showing a structure of a mobile body **100** incorporating a surround surveillance apparatus **200** according to embodiment 1 of the present

invention. Figure **1B** is a side view showing the mobile body **100** of Figure **1A**.

In embodiment 1, a vehicle is described as a specific example of the mobile body **100**.

In embodiment 1, the vehicle **100** incorporates a surround surveillance apparatus **200** for a mobile body. As shown in Figures **1A** and **1B**, the surround surveillance apparatus **200** includes an omniazimuth visual sensor **210** and an arithmetic/control section **220**. The omniazimuth visual sensor **210** is placed on a roof of the vehicle **100**. The arithmetic/control section **220** is provided, for example, in a place near the driver's seat of the vehicle **100**.

The omniazimuth visual sensor **210** shown in Figures **1A** and **1B** has an omniazimuth view filed with a 360° view field around itself in a generally horizontal direction.

Figure **1C** is a plan view showing a structure of a mobile body **100A** incorporating a surround surveillance apparatus **200A** according to embodiment 1 of the present

invention. Figure **1D** is a side view showing the mobile body **100A** of Figure **1C**. The vehicle **100A** incorporates a surround surveillance apparatus **200A** for a mobile body. As shown in Figures **1C** and **1D**, the surround surveillance apparatus **200A** includes a first omniazimuth visual sensor **210A**, a second omniazimuth visual sensor **210B**, and an arithmetic/control section **220**. The first omniazimuth visual sensor **210A** is placed on a front side of the vehicle **100A** (forward direction side of the vehicle **100A**). The second omniazimuth visual sensor **210B** is placed on a rear side of the vehicle **100A** (backward direction side of the vehicle **100A**). The arithmetic/control section **220** is provided in a place near the driver's seat of the vehicle **100A**.

The vehicle **100A** further includes a front bumper **110** and a rear bumper **120**.

In embodiment 1, the first omniazimuth visual sensor **210A** is placed on the central portion of the front bumper **110**, and the second omniazimuth visual sensor **210B** is placed on the central portion of the rear bumper **120**. Each of the first omniazimuth visual sensor **210A** and the second omniazimuth visual sensor **210B** has an omniazimuth

view filed with a 360° view field around itself in a generally horizontal direction.

However, a half of the view field (about 180° rear view field) of the first omniazimuth visual sensor **210A** is blocked by the vehicle **100A**. That is, the effective view field of the first omniazimuth visual sensor **210A** is limited to the 180° frontal view field (from the left side to the right side of the vehicle **100A**). Similarly, a half of the view field (about 180° frontal view field) of the second omniazimuth visual sensor **210B** is blocked by the vehicle **100A**. That is, the effective view field of the second omniazimuth visual sensor **210B** is limited to the 180° rear view field (from the left side to the right side of the vehicle **100A**).

Figure **2** is a block diagram showing a configuration of the surround surveillance apparatus **200** according to embodiment 1.

The surround surveillance apparatus **200** includes: the omniazimuth visual sensor **210** for converting an image obtained from the surroundings of the omniazimuth visual sensor **210** into an image data; and the

arithmetic/control section **220** for processing the image data converted by the omniazimuth visual sensor **210** and displaying an image corresponding to the processed image data. It should be noted that the surround surveillance

5 apparatus **200A** shown in Figures **1C** and **1D** has substantially the same function as that of the surround surveillance apparatus **200** except that the surround surveillance apparatus **200A** includes two omniazimuth visual sensors. Furthermore, each of the first

10 omniazimuth visual sensor **210A** and the second omniazimuth visual sensor **210B** shown in Figures **1C** and **1D** has substantially the same function as that of the omniazimuth visual sensor **210**.

15   The omniazimuth visual sensor **210** includes: an optical system **212** capable of obtaining an image with a view field area therearound and capable of central projection transformation of the image; and an imaging section **214** for converting the image obtained by the

20 optical system **212** into image data. The imaging section **214** includes: an imaging lens **216**; a light receiving section **217** for receiving a central-projection-converted optical image; and an image data generation section **218** for converting the optical image

received by the light receiving section **217** into image

data.

The arithmetic/control section **220** includes: an

5　image processor **230** for converting image data converted

by the imaging section **214** into at least one of panoramic

image data and perspective image data; a display

section **240** for displaying an output **236** from the image

processor **230**; and a display control section **250** for

10　controlling, based on an output **238** from the image

processor **230** and/or an externally-supplied input **254**,

the selection among images of surroundings of the

vehicle **100** (Figures **1C** and **1D**) and the size of the

selected image to be displayed on the display section **240**.

15　The image processor **230** outputs an output **262** to an alarm

generation section **260**, when necessary, so that the alarm

generation section **260** generates an alarm. The image

processor **230** includes an image transformation

section **232**, an output buffer memory **234**, and a storage

20　section **235**. The display section **240** displays at least

one of a panoramic image corresponding to panoramic image

data and a perspective image corresponding to perspective

image data. The storage section **235** stores data for the

image processing process performed in the image

processor **230**. For example, the storage section **235** stores a bird's-eye image of the vehicle **100** or **100A** which has been captured from a position right above the vehicle **100** or **100A**.

For example, the image processor **230** can be placed in an engine compartment at the frontal end of the vehicle **100** or in a luggage compartment at the rear end of the vehicle **100**. The display section **240** and the display control section **250** can be placed in or beside a front panel near the driver's seat.

Hereinafter, each of the above components is described in detail.

Figure **3** shows a specific example of the optical system **212** capable of central projection transformation.

Herein, the optical system **212** includes a hyperboloidal mirror **310** which has a shape of one sheet of a two-sheeted hyperboloid. The imaging lens **216** and the hyperboloidal mirror **310** are positioned such that the optical axis (z-axis) **312** of the hyperboloidal mirror **310** is identical with the optical axis **314** of the imaging

lens **216** included in the imaging section **214**. The first principal point **215** of the imaging lens **216** is located at one of focal points of the hyperboloidal mirror **310** (focal point ②). In such a structure, central

5 projection transformation is possible, i.e., an image obtained by the imaging section **214** corresponds to an image around the hyperboloidal mirror **310**, which is seen from the focal point ① of the hyperboloidal mirror **310**. The optical system **212** having such a structure is

10 disclosed in, for example, Japanese Laid-Open Publication No. 6-295333, and only several features of the optical system are herein described.

In Figure **3**, the hyperboloidal mirror **310** is

15 formed by providing a mirror on a convex surface of a body defined by one of curved surfaces obtained by rotating hyperbolic curves around a z-axis (two-sheeted hyperboloid), i.e., a region of the two-sheeted hyperboloid where Z>0. This two-sheeted hyperboloid is

20 represented as:

$$(X^2+Y^2)/a^2-Z^2/b^2=-1$$
$$c^2=(a^2+b^2) \qquad \ldots\ldots(1)$$

where a and b are constants for defining a shape of the
hyperboloid, and c is a constant for defining a focal point
of the hyperboloid. Hereinafter, the constants a, b,
and c are generically referred to as "mirror constants".
5 Since the hyperboloidal mirror **310** has a curved surface
obtained by rotating a hyperbolic curve, the rotation axis
of the hyperbolic curve is identical with the optical
axis **312** of the hyperboloidal mirror **310**.

10   The hyperboloidal mirror **310** has two focal
points ① and ②. All light from outside which travels
toward one of these focal points (in this case, focal
point ①) is reflected by the hyperboloidal mirror **310** so
as to reach the other focal point (in this case, focal
15 point ②). The hyperboloidal mirror **310** and the imaging
section **214** are positioned such that the optical axis **312**
of the hyperboloidal mirror **310** is identical with the
optical axis **314** of the imaging lens **216** of the imaging
section **4b**, and the first principal point **215** of the
20 imaging lens **216** is located at focal point ②. With such
a configuration, an image obtained by the imaging
section **214** corresponds to an image which is always seen
from focal point ① of the hyperboloidal mirror **310**
regardless of a viewing direction and which can be

converted into image data. It should be noted that, in this case, an image inside the hyperboloidal mirror **310** cannot be obtained. Furthermore, since the imaging section **214** has a certain size, the imaging section **214**

5   does not receive light which is blocked by the imaging section **214** from reaching focal point ① of the hyperboloidal mirror **310**.

The imaging section **214** may be a video camera.

10   The imaging section **214** converts an optical image obtained through the hyperboloidal mirror **310** of Figure **3** into image data using a solid-state imaging device, such as CCD, CMOS, etc. The converted image data is transmitted to the image processor **230**.

15

Figure **4A** is a block diagram showing a structure of the image processor **230**.

The image processor **230** includes the image

20   transformation section **232** and the output buffer memory **234**. The image transformation section **232** includes an A/D converter **410**, an input buffer memory **420**, a CPU **430**, a lookup table (LUT) **440**, and an image transformation logic **450**. Each component of the image

transformation section **232** is connected to the output buffer memory **234** via a bus line **460**.

Figure **4B** is a block diagram showing a structure of the image transformation section **232**.

The image transformation section **232** receives image data obtained by converting an optical image obtained by the imaging section **214**. When the image data is an analog signal, the analog signal is converted by the A/D converter **410** into a digital signal, and the digital signal is transmitted to the input buffer memory **420**. When the image data is a digital signal, the image data is directly transmitted to the input buffer memory **420**.

In the image transformation section **232**, an output (image data) from the input buffer memory **420** is subjected to image processing when necessary. For example, the image transformation logic **450** uses the LUT **440** so as to transform the image data into at least one of panoramic image data and perspective image data, or so as to translationally (vertically/horizontally) move or scale-up/scale-down an image to be displayed.

After image processing, the processed image data is input to the output buffer memory **234** shown in Figure **4A**. During processing, the components are controlled by the CPU **430**. The CPU **430** may be a RISC (reduced instruction set computer) or a CISC (complex instruction set computer).

A principle of the image transformation by the image transformation logic **450** is now described. The image transformation includes a panoramic transformation for obtaining a panoramic (360°) image and a perspective transformation for obtaining a perspective image. Furthermore, a perspective image can be horizontally and rotationally transferred (horizontal transfer, so-called "pan movement") and vertically and rotationally transferred (vertical transfer, so-called "tilt movement"). In this specification, at least one of the horizontal rotational transfer and the vertical rotational transfer is referred to as a "translational transfer".

First, a panoramic (360°) image transformation is described with reference to Figure 5. Referring to part **(a)** of Figure **5**, an image **510** is a round-shape image

obtained by the imaging section **214**. Part **(b)** of Figure **5** shows a donut-shape image **515** subjected to the panoramic image transformation. Part **(c)** of Figure **5** shows a panoramic image **520** obtained by transforming the image **510** into a rectangular coordinate.

Part **(a)** of Figure **5** shows the input round-shape image **510** which is formatted in a polar coordinate form in which the center point of the image **510** is positioned at the origin (Xo,Yo) of the coordinates. In this polar coordinate, a pixel P in the image **510** is represented as $P(r,\theta)$. Referring to part **(c)** of Figure **5**, in the panoramic image **520**, a point corresponding to the pixel P in the image **510** (part **(a)** of Figure **5**) can be represented as P2(x,y). When the round-shape image **510** shown in part **(a)** of Figure **5** is transformed into the square panoramic image **520** shown in part **(c)** of Figure **5** using a point PO(ro,θo) as a reference point, this transformation is represented by the following expressions:

$$x = \theta - \theta o$$
$$y = r - ro$$

When the input round-shape image **510** (part **(a)** of Figure **5**) is formatted into a rectangular coordinate such that the center point of the round-shape image **510** is positioned at the origin of the rectangular coordinate

5   system, (Xo,Yo), the point P on the image **510** is represented as (X,Y). Accordingly, X and Y are represented as:

$$X = Xo + r \times \cos\theta$$

10    $$Y = Yo + r \times \sin\theta$$

Thus,

$$X = (y + ro) \times \cos(x + \theta o) + Xo$$

15    $$Y = (y + ro) \times \sin(x + \theta o) + Yo$$

The pan/tilt movement for a panoramic image can be achieved by changing the position of the reference point PO(ro,θo) to another position. The pan movement is

20   achieved by changing the value of "θo". The tilt movement is achieved by changing the value of "ro". However, in embodiment 1, the tilt movement is not performed because the resultant image leaves the transformation region.

Next, a perspective transformation is described with reference to Figure **6**. In the perspective transformation, the position of a point on the input optical image obtained by a light receiving section **217**
5 of the imaging section **214** which corresponds to a point in a three-dimensional space is calculated, and image information at the point on the input optical image is allocated to a corresponding point on a perspective-transformed image, whereby coordinate transformation is
10 performed.

In particular, as shown in Figure **6**, a point in a three-dimensional space is represented as P3, a point corresponding thereto which is on a round-shape image
15 formed on a light receiving plane of a light receiving section **217** of the imaging section **214** is represented as $R(r,\theta)$, and the focal distance of the imaging lens **216** is F. The light receiving section **217** is placed at a position which is distant from the imaging lens **216** by
20 the focal distance F. Further, mirror constants of the hyperboloidal mirror **310** are (a, b, c), which are the same as a, b, and c in Figure **3**. With these parameters, expression (2) is obtained:

$$r = F \times \tan((\pi/2)-\beta) \quad \ldots (2)$$

In Figure **6**, α is an incident angle of light which travels from an object point (point P3) toward focal point ① with respect to a horizontal plane including focal point ①; β is an incident angle of light which comes from point P3, is reflected at a point on the hyperboloidal mirror **310**, and enters into the imaging lens **216** (note that angle β is not an angle with respect to the optical axis **314** of the imaging lens **216** but an angle with respect to a surface of the imaging lens **216** which is perpendicular to the optical axis **314**). Algebraic numbers α, β, and θ are represented as follows:

$$\beta = \arctan(((b^2+c^2) \times \sin\alpha - 2 \times b \times c)/(b^2-c^2) \times \cos\alpha)$$

$$\alpha = \arctan(tz/\mathrm{sqrt}(tx^2+ty^2))$$

$$\theta = \arctan(ty/tx)$$

From the above, expression (2) is represented as follows:

$$r = F \times (((b^2-c^2) \times \mathrm{sqrt}(tx^2+ty^2))/((b^2+c^2) \times tz - 2 \times b \times c$$
$$\times \mathrm{sqrt}(tx^2+ty^2+tz^2))) \quad \ldots (2')$$

The coordinate of a point on the round-shape image **510**

is transformed into a rectangular coordinate R (X,Y). X
and Y are represented as:

$\qquad$ X = r×cosθ $\qquad$ ...(3)

5 $\qquad$ Y = r×sinθ $\qquad$ ...(4)

Accordingly, from the above expressions:

$\qquad$ X = F×(((b²-c²)×tx/((b²+c²)×tz-2×b×c

10 $\qquad\qquad\qquad\qquad$ ×sqrt(tx²+ty²+tz²))) ...(5)

$\qquad$ Y = F×(((b²-c²)×ty/((b²+c²)×tz-2×b×c

$\qquad\qquad\qquad\qquad$ ×sqrt(tx²+ty²+tz²))) ...(6)

$\qquad$ Next, the horizontal rotational transfer and the

15 vertical rotational transfer are described.

$\qquad$ Now, referring to Figure **6**, consider a square
image plane having width W and height h located in the
three-dimensional space at a position corresponding to

20 a rotation angle θ around the Z-axis **312** where R is a
distance between the plane and focal point ① of the
hyperboloidal mirror **310**, and φ is a depression angle
(which is equal to the incident angle α). The center of
the square image plane is point P3. Parameters of a point

at the upper left corner of the square image plane, point Q (tx,ty,tz), are represented as follows:

$$tx = (R\cos\phi+(h/2)\sin\phi)\cos\theta-(W/2)\sin\theta \quad ...(7)$$

$$ty = (R\cos\phi+(h/2)\sin\phi)\sin\theta-(W/2)\cos\theta \quad ...(8)$$

$$tz = R\sin\phi-(h/2)\cos\phi \quad ...(9)$$

By combining expressions (7), (8), and (9) into expressions (5) and (6), it is possible to obtain the coordinate (X,Y) of a point on the round-shape image formed on the light receiving section **217** of the imaging section **214** which corresponds to point Q of the square image plane as follows:

$$X = F\times(((b^2-c^2)\times((R\cos\phi+(h/2)\sin\phi)\times\cos\theta$$
$$-(W/2)\sin\theta)/((b^2+c^2)\times(R\sin\phi-(h/2)\cos\phi)$$
$$-2\times b\times c\times sqrt(R^2+(W/2)^2+(h/2)^2))) \quad ...(10)$$

$$Y = F\times(((b^2-c^2)\times((R\cos\phi+(h/2)\sin\phi)\times\sin\theta$$
$$-(W/2)\cos\theta)/((b^2+c^2)\times(R\sin\phi-(h/2)\cos\phi)$$
$$-2\times b\times c\times sqrt(R^2+(W/2)^2+(h/2)^2))) \quad ...(11)$$

Furthermore, assume that the square image plane is transformed into a perspective image divided into pixels each having a width n and a height m. In expressions (7),

(8), and (9), the parameter W is changed in a range from
W to -W by units of W/n, and the parameter h is changed
in a range from h to -h by units of h/m, whereby coordinates
of points on the square image plane are obtained.

5   According to these obtained coordinates of the points on
the square image plane, image data at points on the
round-shape image formed on the light receiving
section **217** which correspond to the points on the square
image plane is transferred onto a perspective image so

10 as to be displayed on the display section **240** (Figure **2**).

    Next, a horizontal rotational movement (pan
movement) and a vertical rotational movement (tilt
movement) in the perspective transformation are described.

15 First, a case where point Q as mentioned above is
horizontally and rotationally moved (pan movement) is
described. A coordinate of a point obtained after the
horizontal rotational movement, point Q' (tx',ty',tz'),
is represented as follows:

20

$$tx' = (R\cos\phi+(h/2)\sin\phi)\cos(\theta+\Delta\theta)$$
$$-(W/2)\sin(\theta+\Delta\theta) \quad ...(12)$$
$$ty' = (R\cos\phi+(h/2)\sin\phi)\sin(\theta+\Delta\theta)$$
$$+(W/2)\cos(\theta+\Delta\theta) \quad ...(13)$$

$$tz' = R\sin\phi-(h/2)\cos\phi \qquad \ldots(14)$$

where $\Delta\theta$ denotes a horizontal movement angle.

5   By combining expressions (12), (13), and (14) into expressions (5) and (6), the coordinate (X,Y) of a point on the round-shape image **510** formed on the light receiving section **217** which corresponds to the point Q' (tx',ty',tz') can be obtained. This applies to other points (other than point Q) on the round-shape image **510**. In expressions (12), (13), and (14), the parameter W is changed in a range from W to -W by units of W/n, and the parameter h is changed in a range from h to -h by units of h/m, whereby coordinates of points on the square image plane are obtained. According to these obtained coordinates of the points on the square image plane, image data at points on the round-shape image **510** formed on the light receiving section **217** which correspond to the point Q' (tx',ty',tz') is transferred onto a perspective image, whereby a horizontally rotated image can be obtained.

Next, a case where point Q as mentioned above is vertically and rotationally moved (tilt movement) around

the Z-axis **312** is described. A coordinate of a point obtained after the vertical rotational movement, point Q" (tx",ty",tz"), is represented as follows:

5

$$tx" = (R\cos(\phi+\Delta\phi)+(h/2)\sin(\phi+\Delta\phi)\times\cos\theta-$$

$$(W/2)\sin\theta \quad ...(15)$$

$$ty" = (R\cos(\phi+\Delta\phi)+(h/2)\sin(\phi+\Delta\phi)\times\sin\theta+(W/2)\cos\theta \quad ...(16)$$

$$tz" = R\sin(\phi+\Delta\phi)-(h/2)\cos(\phi+\Delta\phi) \quad ...(17)$$

10

where $\Delta\phi$ denotes a vertical movement angle.

By combining expressions (15), (16), and (17)
into expressions (5) and (6), the coordinate (X,Y) of a
15 point on the round-shape image **510** formed on the light
receiving section **217** which corresponds to the point Q"
(tx",ty",tz") can be obtained. This applies to other
points on the round-shape image. In expressions (15),
(16), and (17), the parameter W is changed in a range from
20 W to -W by units of W/n, and the parameter h is changed
in a range from h to -h by units of h/m, whereby coordinates
of points on the square image plane are obtained.
According to these obtained coordinates of the points on
the square image plane, image data at points on the

round-shape image **510** formed on the light receiving section **217** which correspond to the point Q" (tx",ty",tz") is transferred onto a perspective image, whereby a vertically rotated image can be obtained.

Further, a zoom-in/zoom-out function for a perspective image is achieved by one parameter, the parameter R. In particular, when the parameter R in expressions (4) through (12) is decreased while the parameters W and h are fixed, a view range from focal point ① is decreased, so that an image equivalent to a zoomed-out image which can be obtained by a zoom-out operation of the optical system is obtained. When the parameter R in expressions (4) through (12) is increased while the parameters W and h are fixed, a view range from focal point ① is increased, so that an image equivalent to a zoomed-in image which can be obtained by a zoom-in operation of the optical system is obtained.

For example, consider a case where the omniazimuth visual sensor **210** is attached to the vehicle **100** such that the optical axis **314** of the imaging section **214** is perpendicular to the ground. When the viewing direction of a perspective image is selected by the vertical

rotational transfer such that α=-90°, a perspective view
obtained is a bird's-eye view of the vehicle **100** and
surroundings thereof which is seen downward from a
position right above the vehicle **100**. In this case, the
5 viewing area can be enlarged by decreasing the parameter R
as described above so as to obtain a zoomed-out view,
whereas a zoomed-in view can be obtained by increasing
the parameter R. Furthermore, by performing a zoom-in
operation by control of the display control section **250**
10 (e.g., a key operation), a bird's-eye view seen downward
from a position right above the entire vehicle **100** which
shows a certain area around the omniazimuth visual
sensor **210** shown in Figures **1A** and **1B** and which covers
the vehicle **100**.

15

In the present specification, a "bird's-eye view"
is a view seen from a position above the mobile body **100**
in a direction perpendicular to the most likely moving
direction of the mobile body **100**.

20

Furthermore, in the present specification, the
"most likely moving direction" is a direction in which
the mobile body **100** moves with the highest probability.
Generally,   the   mobile   body   **100**   is   designed   in

consideration of the most likely moving direction. Moreover, an operator of the mobile body **100** generally faces the most likely moving direction of the mobile body **100**.

5

Furthermore, in the above example, a perspective view obtained by the omniazimuth visual sensor **210** is on a plane which is perpendicular to a selected viewing direction from focal point ① (e.g., in Figure **6**, a

10 direction from focal point ① to point P3), and the range of the obtained perspective view equally extends on the plane around the line of the selected viewing direction from focal point ①. However, according to the present invention, it is apparent that by using expressions (5)

15 and (6), any perspective view can be obtained from a plane within a three-dimensional space covered by the optical system of the omniazimuth visual sensor **210**, and the plane from which such a perspective view is obtained may form any angle with respect to a selected viewing angle. For

20 example, when the omniazimuth visual sensor **210** is placed at a corner of the generally rectangular vehicle **100** rather than on the roof of the vehicle **100**, an image display on the display screen of the display section **240** may not show the vehicle **100** at the center of the display

screen of the display section **240** because the range of the obtained perspective view equally extends around the line of the selected viewing direction from focal point ①.

5

In such a case, the image display on the display section **240** can be shifted such that the vehicle **100** is shown in the center of the image by shifting the variable range of parameters W and h in above expressions (15),

10 (16), and (17). For example, consider a case where the width of the vehicle **100** is 2lw. In this case, in expressions (15), (16), and (17), the range of the image plane is vertically and horizontally shifted by (μ,ν) (where $lw=\sqrt{(\mu^2+\nu^2)}$), i.e., the range of the image plane

15 is shifted from "W to -W (width)" and "h to -h (height)" to "W+μ to -W+μ" and "h+ν to -h+ν", respectively, whereby the vehicle **100** is shown in the center of the image displayed on the display section **240**. Such processing can be achieved by adding μ and ν to the parameters W and

20 h, respectively, in the transformation processing of the image processor **230**.

Referring now to Figure **2**, the display section **240** is, for example, a monitor using a cathode

ray tube, LCD, EL, etc. The display section **240** receives an output from the output buffer memory **234** of the image processor **230** so as to display an image based on the received output. During this image display operation,

5   the display control section **250** including a microcomputer can select an image to be displayed on the display section **240** (panoramic image and/or perspective image transformed by the image processor **230**), and/or control the direction and size of an image to be displayed, etc.

10

Figure **7** shows a display screen **710** of the display section **240**.

In Figure **7**, the display screen **710** includes: a

15   first perspective image display window **720**; a second perspective image display window **730**; a third perspective image display window **740**; and a panoramic image display window **750**. In the default state, the first perspective image display window **720** displays a frontal view field

20   perspective image from the vehicle **100**; the second perspective image display window **730** displays a left view field perspective image from the vehicle **100**; and the third perspective image display window **740** displays a right view field perspective image from the vehicle **100**.

The panoramic image display window **750** presents a panoramic image showing all around the vehicle **100**.

The display screen **710** further includes: a first

5   explanation display window **725** for showing an explanation of the first perspective image display window **720**; a second explanation display window **735** for showing an explanation of the second perspective image display window **730**; a third explanation display window **745** for

10 showing an explanation of the third perspective image display window **740**; and a fourth explanation display window **755** for showing an explanation of the panoramic image display window **750**.

15   The display screen **710** further includes: a direction key **760** for vertically/horizontally scrolling perspective images to be displayed; a scale-up key **770** for scaling up images; and a scale-down key **780** for scaling down images.

20

The first through fourth explanation display windows **725, 735, 745,** and **755** function as switches for activating the image display windows **720, 730, 740,** and **750,** respectively. A user activates a desired image

display window (window **720, 730, 740,** or **750**) by means
of a corresponding explanation display window (window **725,
735, 745,** or **755**) which functions as a switch, whereby
the user can vertically/horizontally scroll and
5   scale-up/down the image displayed in the activated window.
Further, whether or not an image display window
(window **720, 730, 740,** or **750**) is active may be indicated
by the change of the display color of the corresponding
explanation display window (window **725, 735, 745,** or **755**).
10 The user can translationally (vertically/horizontally)
scroll and/or scale-up/down the image displayed in each
of the perspective image display windows **720, 730,** and
740 using the direction key **760,** the scale-up key **770,**
and the scale-down key **780.** The user can translationally
15 (vertically/horizontally) scroll and/or scale-up/down
the image displayed in the panoramic image display
window **750** by using the direction key **760.** However, the
image displayed in the panoramic image display window **750**
is not scaled-up or scaled-down.

20

For example, when the user touches the first
explanation display window **725,** a signal is output to the
display control section **250** (Figure **2**). In response to
the touch, the display control section **250** changes the

display color of the first explanation display window **725** or allows the first explanation display window **725** to flicker so as to indicate that the first perspective image display window **720** is active. Meanwhile, the first
5 perspective image display window **720** becomes active, and the user can vertically/horizontally scroll and scale-up/down the image displayed in the window **720** using the direction key **760**, the scale-up key **770**, and the scale-down key **780**. In particular, signals are sent from
10 the direction key **760**, the scale-up key **770**, and the scale-down key **780** through the display control section **250** to the image transformation section **232** of the image processor **230** (Figure 2). According to the signals from the direction key **760**, the scale-up key **770**,
15 and the scale-down key **780**, an image is transformed, and the transformed image is transmitted to the display section **240** (Figure 2) and displayed on the screen of the display section **240**.

20   The display screen **710** may further include an omniazimuth visual sensor switching key **790**.

For example, a driver uses the omniazimuth visual sensor switching key **790** located on the display

screen **710**, and based on the operation of the switching key **790** by the driver, a signal is transmitted from the display control section **250** to the image processor **230** and the display section **240**, whereby switching is performed between a frontal omniazimuth visual sensor (**210A** in Figures **1C** and **1D**) and a rear omniazimuth visual sensor (**210B** in Figures **1C** and **1D**) such that a visual sensor is selected. When the rear omniazimuth visual sensor **210B** is selected, for example, an image derived from the rear omniazimuth visual sensor **210B** is displayed. Thereafter, for example, the first perspective image display window **720** is selected from among the perspective image display windows **720**, **730**, and **740**, and the image display in the window **720** is tilted up to -90° by the direction key **760**, a bird's-eye image seen from a position right above the rear part of the vehicle **100A** is obtained as described above. An example of such a bird's-eye image is shown in Figure **8**.

Figure **8** shows another exemplary display screen **810** of the display section **240**.

As shown in Figure **8**, the display screen **810** can displays only an enlarged first perspective image display

windows **830**. A first explanation display window **820** indicates that the first perspective image display windows **830** shows a rear bird's-eye image of the rear portion of vehicle **100A** and surroundings thereof. This
5 display of a bird's-eye image is useful when the driver has to check the distance between his/her own vehicle and adjacent vehicles or obstacles: for example, especially when the driver parks the vehicle in a carport or parking lot or drives the vehicle out of the carport or parking
10 lot, or when the driver parks or stops the vehicle as close to the edge of the adjacent vehicles or obstacles as possible.

In the example illustrated in Figure **8**, an
15 omniazimuth visual sensor **210B** is placed at a corner of the vehicle **100**. (Such an arrangement is described later in detail in embodiment 2.) In this case, about one fourth of the view field (about 90°) of the omniazimuth visual sensor **210B** (area **860** in Figure **8**) is blocked by
20 the vehicle **100**. That is, the view field of the omniazimuth visual sensor **850** is about 270°, which is wider as compared with the omniazimuth visual sensor **210B** placed on the central portion of the rear bumper **120** (see Figures **1C** and **1D**) which has about 180° rear view field.

Furthermore, each of the images displayed on the second perspective image display window **730** and the third perspective image display window **740** (Figure **7**) can be horizontally shifted by any angle within the 360° rotatable range. For example, when an image displayed on the second perspective image display window **730** or the third perspective image display window **740** is horizontally rotated by 90°, a frontward or backward perspective image of the vehicle **100** can be obtained. Furthermore, the display section **240** may be arranged such that the display screen can be switched between the display screen **710** (Figure **7**) and the display screen **810** (Figure **8**) by a single operation of an additional switch provided on the display screen.

(Embodiment 2)

Figure **9A** is a plan view showing a vehicle **900** which includes a surround surveillance apparatus **1000** for a mobile body according to embodiment 2 of the present invention. Figure **9B** is a side view of the vehicle **900**.

Differences between the vehicle **900** of embodiment 2 and the vehicle **100A** of embodiment 1 reside

in that an omniazimuth visual sensor **1010A** is placed on the front right corner of the vehicle **900**, and an omniazimuth visual sensor **1010B** is placed on the rear left corner of the vehicle **900** diagonally to the sensor **1010A**.

5

Each of the omniazimuth visual sensors **1010A** and **1010B** has an ominizimuth view field with a 360° view field around itself in a generally horizontal direction. However, one fourth of the view field (a left-hand half

10 of the rear view field (90°)) of the omniazimuth visual sensor **1010A** is blocked by the vehicle **900**. That is, the effective view field of the omniazimuth visual sensor **1010A** is limited to about 270° front view field. Similarly, one fourth of the view field (a right-hand half

15 of the front view field (90°)) of the omniazimuth visual sensor **1010B** is blocked by the vehicle **900**. That is, the effective view field of the omniazimuth visual sensor **1010B** is limited to about 270° rear view field. Thus, with these two omniazimuth visual sensors **1010A**

20 and **1010B**, an about 360° view field image of the surroundings of the entire vehicle **900** can be obtained such that the omniazimuth visual sensors **1010A** and **1010B** can see areas in close proximity to the vehicle **900** which are the blind areas of the vehicle **100** of embodiment 1.

For example, referring to the example illustrated in Figure **7**, consider a case where the driver selects the first perspective image display window **720** and uses the direction key **760** so as to show a bird's-eye image of the vehicle **900**. In this case, if image data obtained through the omniazimuth visual sensor **1010A** is used without being specifically transformed, the vehicle **900** may not be displayed in the center of the display screen. According to this embodiment, when such occurs, the image data obtained through the omniazimuth visual sensor **1010A** can be transformed according to the transformation methods as described in embodiment 1 such that the vehicle **900** is displayed at a predetermined position (e.g., center) of the display screen as shown in, for example, Figure **10**.

Figure **10** shows an exemplary display screen **1110** according to embodiment 2. In embodiment 2, the image processor **230** or the display section **240** can combine a bird's-eye image obtained through the omniazimuth visual sensor **1010A** located at a front right corner and a bird's-eye image obtained through the omniazimuth visual sensor **1010B** located at a left rear corner diagonally to

the sensor **1010A** so as to display surroundings of the vehicle **900** on the display screen **1110** at one time as shown in Figure **10**.

5   It should be noted that when an omniazimuth visual sensor is positioned so as to be higher than the main body (or roof) of a vehicle, a bird's-eye image of the vehicle and surroundings thereof which is seen from a position right above the vehicle can be obtained. However, when

10   the omniazimuth visual sensor is positioned so as to be lower than the main body (or roof) of a vehicle, the omniazimuth visual sensor can obtain only an image showing a side face(s) of the vehicle. In such a case, in order to display a bird's-eye image showing the entire vehicle,

15   a top view image of the vehicle and surroundings thereof which was previously captured from a position directly above the vehicle or which was previously created by using computer graphics software is prepared, and this top view image is displayed in a superimposed manner at a

20   predetermined position within a displayed image on the display screen so as to be combined with the image obtained through the omniazimuth visual sensor. With such a display function, the driver of the vehicle can readily check the surroundings of the vehicle. For example, in

a parking place, the driver of the vehicle can readily

grasp a distance between the vehicle and white lines or

obstacles.

5   Furthermore, as shown in Figure 11, when images

obtained through the omniazimuth visual sensors 1010A

and 1010B which are located at the diagonal corners of

the vehicle 900 are combined, the both sensors 1010A

and 1010B can obtain images of region 1 and region 4. In

10   such a case, an image of region 1 (or region 4) is

displayed by selectively using an image derived from the

sensor 1010A and an image derived from the sensor 1010B.

However, when such a display method is used, a visual

discontinuity is caused at an interface between an image

15   derived from a selected omniazimuth visual sensor and an

image derived from the other omniazimuth visual sensor

(e.g., interface between region 1 or 4 and region 2 or 3)

due to the difference of the viewing angle between the

sensors 1010A and 1010B.   Such a visual discontinuity

20   causes difficulty and discomfort on the driver of the

vehicle 900 in seeing the displayed image.

In order to avoid such a problem, there is provided

a switching key 790 on the display screen which is

connected to the display control section **250**. In response to a switching operation of the driver using the switching key **790**, a signal is transmitted to the display control section **250**. According to the signal from the

5   switching key **790**, one of the sensors **1010A** and **1010B** is selected for display an image of region 1 or 4 such that an image of a region to which the driver is paying greater attention and an image of a region adjacent to this region are combined so as to provide a smoothly combined display

10 image to the driver. For example, when the driver of the vehicle **900** is paying greater attention to an area between region 1 and region 3 rather than an area between region 1 and region 2, the driver can use the switching key **790** to select an image of region 1 which is obtained through

15 the sensor **1010A** such that a displayed image is visually smooth at the interface between region 1 and region 3 whereas a visual discontinuity is caused at the interface between region 1 and region 2. Conversely, when the driver uses the switching key **790** to select an image of

20 region 1 which is obtained through the sensor **1010B** such that a displayed image is visually smooth at the interface between region 1 and region 2 whereas a visual discontinuity is caused at the interface between region 1 and region 3.

(Embodiment 3)

Figure **12A** is a plan view showing a structure of a vehicle **1200** incorporating a surround surveillance apparatus **1300** according to embodiment 3 of the present invention. Figure **12B** is a side view showing the vehicle of Figure **12A**.

The surround surveillance apparatus **1300** shown in Figures **12A** and **12B** is different from the surround surveillance apparatus **1000** in that a temperature measurement section **270** is provided at a position on the external surface of the vehicle **1200** which is optimum for measuring the environmental temperature (e.g., a frontal portion of the roof).

Figure **13** is a block diagram showing a configuration of the surround surveillance apparatus **1300** according to embodiment 3. The surround surveillance apparatus **1300** is different from the surround surveillance apparatus **200** of Figure **2** in that an arithmetic/control section **1320** of the apparatus **1300** includes the temperature measurement section **270**.

In embodiment 3, as mentioned above, the temperature measurement section 270 is provided at a position on the external surface of the vehicle 1200 which is optimum for measuring the environmental temperature

5 (e.g., a frontal portion of the roof). The temperature measurement section 270 is connected to the display control section 250 of the surround surveillance apparatus 1300 via a cable. When an engine of the vehicle 1200 is started, if a measurement result of the

10 temperature measurement section 270 is equal to or lower than a predetermined temperature, the display control section 250 automatically displays, based on an output 256 from the measurement section 270, for a certain period an image showing the surroundings of the vehicle 1200 at

15 one time in a single display screen, for example, like a bird's-eye image shown in Figure 10. Due to such a structure, even when the environmental temperature of the vehicle 1200 is at or below a predetermined temperature so that the window glass of the vehicle 1200 is fogged

20 and the fogged window inhibits the driver from looking out of the window, the driver can readily check the safety around the vehicle 1200.

In embodiments 1 to 3, the omniazimuth visual

sensor is placed on a roof or a bumper of a vehicle, but may also be placed on a hood, a side mirror, or any other place of the vehicle. Furthermore, in embodiments 1 to 3, a passenger car is illustrated as the vehicle. However,

5   the present invention is not limited thereto, but can be applied to a large vehicle, such as a bus or the like, and a vehicle for cargo. In particular, the present invention is useful for cargo vehicle because in many cargo vehicles a driver's view in the rearward direction

10   of the vehicle is blocked by a cargo compartment. The present invention is applicable to trains. Further, the present invention is applicable to airplanes, and general movable robots.

15   As described hereinabove in detail, according to the present invention, an omniazimuth visual sensor(s) is placed, for example, on a bumper(s), at a corner(s), etc., of a vehicle, whereby a driver's blind areas can be readily observed. With such a system, the driver does

20   not need to switch a plurality of cameras, to select one among these cameras for display on a display device, or to change the orientation of the camera, as in a conventional vehicle surveillance apparatus. Thus, when the driver starts to drive, when the motor vehicle turns

right or left, or when the driver parks the motor vehicle in a carport or parking lot or drives the vehicle out of the carport or parking lot, the driver can check the safety around the vehicle and achieve safe driving.

5

Furthermore, the driver can select a desired display image and change the display direction or the image size. In particular, by switching a display to a bird's-eye view display when the driver parks the vehicle

10 in a carport or parking lot or drives the vehicle out of the carport or parking lot, or when the driver parks or stops the vehicle as close to the edge of the adjacent vehicles or obstacles as possible, the safety around the vehicle can be readily checked (for example, the distance

15 between his/her own vehicle and adjacent vehicles or obstacles can be readily checked), whereby a contact accident(s) or the like can be prevented.

Various other modifications will be apparent to

20 and can be readily made by those skilled in the art without departing from the scope and spirit of this invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein, but rather that the claims be broadly

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construed.